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ABSTRACT

Provided are guidelines for evaluating undergraduate professional education in chemistry. The guidelines summarize an approved program as including: 400 hours of classroom work; 500 hours of laboratory work; a core curriculum covering principles of analytical, inorganic, organic, and physical chemistry; 1 year of advanced work in chemistry or allied fields; and 1 year of physics. Review of a department's program also includes evaluation of: faculty size; teaching loads (maximum- 15 contact hours per week); examinations, syllabi, and student research reports; faculty composition; faculty's professional activities; library collection (minimum- 20 subscriptions to refereed journals and access to Chemical Abstracts); facilities and equipment; budget and administrative structure; textbooks; and placement of graduates. Principal changes from the previous (1977) edition of these guidelines are increased emphases on computer literacy, information retrieval, self-instruction programs, and basic inorganic chemistry (reflected by the movement of the advanced inorganic course from the category of Advanced Courses to the Core Curriculum). Guidelines related to actions after evaluation and re-evaluation, probation and withdrawal of program approval, appeals of adverse evaluation decisions, and procedures for complaints are also provided. (JN)

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Undergraduate Professional Education in Chemistry: Guidelines and Evaluation Procedures

Fall 1983

AMERICAN CHEMICAL SOCIETY

COMMITTEE ON PROFESSIONAL TRAINING

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PREFACE

Founded in 1876, the American Chemical Society (ACS) was chartered as a nonprofit scientific and educational organization by an act of Congress on August 25, 1937. Section 2 of the Charter provides that the Society shall ". . . . encourage in the broadest and most liberal manner the advancement of chemistry in all its branches; the promotion of research in chemical science and industry; the improvement of the qualifications and usefulness of chemists through high standards of professional ethics, education, and attainments; the increase and diffusion of chemical knowledge; and by its meetings, professional contacts, reports, papers, discussions, and publications, to promote scientific interests and inquiry, thereby fostering public welfare and education, aiding the development of our country's industries, and adding to the material prosperity and happiness of our people."

The Society has about 125,000 chemists and chemical engineers as members. They are engaged in a broad spectrum of professional, scientific, and engineering activities within academic, governmental, and industrial enterprises. Most of the members (60%) are employed by industry, 25% by academic institutions, and 15% by other types of employers.

The Committee on Professional Training (CPT) was established in 1936 by a resolution of the ACS Council authorizing the appointment of a committee by the President to study the training of professional chemists and chemical engineers, the Committee to be of a permanent and continuing nature. In 1968 CPT became a Joint Committee of the ACS Board and Council, reporting to both.

The Committee currently consists of twelve members, a consultant, and a nonvoting (staff) secretary. Members are usually appointed to three-year terms and may be reappointed for one or two more terms. All appointments and reappointments are made jointly by the Chairman of the ACS Board of Directors and the President of the Society with the advice of the ACS Committee on Committees. The members of CPT are experienced scientists and educators chosen to represent different fields of chemistry and points of view as well as various types of academic and nonacademic institutions concerned with chemical education and the chemical sciences. Consultants are appointed to the Committee on special occasions to provide expertise and continuity in handling particular matters before it.

The primary objective of the Committee on Professional Training is to help improve the quality of chemical education. It does so in a variety of ways. Key functions are the development of guidelines for high quality undergraduate programs for those students planning careers in chemistry and, upon invitation, the evalua-

tion of institutions that offer programs designed to meet these guidelines. Other activities seek to improve the effectiveness of graduate education.

Extensive records are maintained by the Committee on undergraduate programs at all institutions approved by the Society. The Committee also collects information and reports on trends, developments, and problems in chemical education. It provides assistance to colleges and universities wishing to improve their programs in chemistry, whether the institutions seek a formal evaluation or not. In addition, the Committee cooperates with other professional and educational organizations concerned with maintaining high quality postsecondary education.

In the field of graduate education, the Committee studies and publishes reports on timely and important aspects of graduate training. It compiles and publishes biennially the ACS DIRECTORY OF GRADUATE RESEARCH, which contains information of particular interest to students considering graduate training in chemistry, chemical engineering, biochemistry, pharmaceutical/medicinal chemistry, clinical chemistry, and polymer chemistry. A copy of this publication should be readily available to students, and faculty members should draw the attention of students to its existence and utility.

Committee meetings are held at least twice each year, generally coinciding with the national meetings of the Society. An open meeting of the Committee each year affords members of the Society and others the opportunity to discuss and comment about the activities of the Committee and to offer suggestions.

A report summarizing Committee activities is submitted annually to the ACS Board and Council. The annual reports, which include numbers of graduates (bachelor's, master's, Ph.D.'s) in chemistry from the approved schools and in chemical engineering from the AIChE-ABET accredited chemical engineering departments, are published in *Chemical and Engineering News* each spring, and reprints are available upon request.

Funds to support the Committee and its various activities, with the exception of the ACS DIRECTORY OF GRADUATE RESEARCH, are provided entirely by the American Chemical Society. The Directory is self-supporting, with income derived from payments of page charges by institutions whose faculties are listed and from sales of the Directory. No charges are made by the Society to academic institutions for Committee consultations or for program evaluations.

This booklet discusses the guidelines established by the Society for undergraduate professional education in chemistry and describes the policies and procedures under which programs are evaluated. The guidelines are designed for institutions that offer professional programs in chemistry and are not necessarily applicable to all institutions of higher education that offer the baccalaureate degree with a major in chemistry. There are many institutions, for instance, that, within their stated educational objectives, offer instruction in chemistry that is not intended to be as ex-

tensive as that specified in these guidelines. Similarly, many ACS approved institutions offer other excellent degree programs that require less chemistry than that needed for the professional degree.

The Committee encourages development of programs to serve students who wish to combine a basic education in chemistry with intensive studies in other disciplines. Many careers in the chemical industry, government, and other areas are open to graduates with a good background in chemistry combined with computer science (for chemical information and data retrieval systems); law (for patent work); economics (for sales, purchasing, and market research); library science (for chemical librarians); systems engineering (for work in pollution control, urbanism, and ecology); and history, literature, and philosophy (for literature research and technical editing). A major in chemistry with supporting work in biology has long been a program chosen by many students planning careers in medicine and dentistry. It is not necessary that all chemistry options meet the ACS criteria for a professional career in chemistry or that all chemistry graduates meet ACS certification requirements. Able students from such programs often elect to enter the chemical profession and subsequently have excellent careers.

Correspondence concerning activities of the Committee and requests for its assistance and cooperation should be addressed to the Secretary, Committee on Professional Training, American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. 20036

GUIDELINES FOR EVALUATING UNDERGRADUATE PROFESSIONAL EDUCATION IN CHEMISTRY

SUMMARY OF GUIDELINES*

An approved program includes:

- 400 hours of classroom work in chemistry
- 500 hours of laboratory work in chemistry
- a core curriculum that covers the principles of analytical, inorganic, organic, and physical chemistry
- one year of advanced work in chemistry or allied fields
- one year of physics

The Committee's review of a department's program includes, additionally, evaluation of:

- faculty size (minimum: four chemists; three-fourths with Ph.D.'s in chemistry)
- teaching loads (maximum: 15 contact hours per week)
- examinations, syllabi, and student research reports
- faculty composition
- faculty's professional activities
- library collection (minimum: 20 subscriptions to refereed journals; access to *Chemical Abstracts*)
- facilities and equipment
- budget and administrative structure
- textbooks
- placement of graduates

*Principal changes from the previous (1977) edition of these guidelines are increased emphases on computer literacy, information retrieval, self-instruction programs, and basic inorganic chemistry, as reflected in the latter case by movement of the advanced inorganic course from the category of Advanced Courses to the Core Curriculum, with a concomitant decrease in the number of required Advanced Courses from three to two. It is anticipated that a course in general chemistry may satisfy parts of the core curriculum.

PROGRAM AND ORGANIZATIONAL STRUCTURE

The mission of an active, modern program of chemical education at the undergraduate level transcends the training of professional chemists. Chemistry is important in other disciplines and in the intellectual lives of many students seeking a liberal education. The structure and scope of any particular undergraduate program in chemistry are governed by the overall educational objectives and resources of the institution in relation to the needs of the students and other constituencies whom it seeks to serve. For there to be a sound, complete program that prepares its students for professional work in chemistry, there must be not only a strong institutional commitment of resources to this objective but also an availability of capable students sufficient in number to justify its continuation.

Also, evidence must exist of the continued ability of the entire program to serve effectively all students within the institution, recognizing their different needs, interests, and career goals. Another important consideration for specialized programs in chemistry and/or related scientific fields is the adequacy and long-range availability of suitable positions for the students seeking careers in these fields. Moreover, the institution should have established procedures for periodic self-evaluation of the effectiveness of its program and evidence of the program's achievements and compatibility with other institutional objectives.

The chemistry program should be administered by a chemistry department organized as an independent unit with control of an adequate budget. The department should be involved in and exercise reasonable control over matters pertaining to faculty selection and promotion, course development, assignment of teaching responsibilities, grading standards, and similar intradepartmental activities. At those institutions where the department is administered as a division of a larger unit, it is essential that the chemistry faculty have enough autonomy to carry out properly these functions and responsibilities within the division.

Improvements in educational and employment opportunities in professional areas for women and minority groups are of interest to the Committee. Institutions are encouraged to take active and positive roles in assuring equal opportunity in education and employment.

FINANCIAL SUPPORT

An adequate level of financial support, with continuity and stability, is essential to a strong and modern program of education in chemistry. The institution must es-

tablish its ability and willingness to make such a financial commitment, and the level should be consistent and reasonable in relation to the overall resources of the institution and its educational goals.

Financial support by the institution is necessary for the following:

- a permanent chemistry faculty of sufficient size and scientific breadth to offer the variety and level of chemistry courses specified in these criteria
- enough nonacademic personnel for secretarial services, stockroom administration, and instrument and equipment maintenance
- expendable supplies and capital equipment acquisitions and replacements as required for high quality laboratory instruction
- equipment maintenance and repair
- a suitable amount and variety of library and learning resources including scientific periodicals, other reference materials, and computer facilities
- student and faculty research
- staff travel to professional meetings
- sabbatical leaves for tenured faculty

THE CURRICULUM

Introduction

The principal purpose of the American Chemical Society's program of approval of undergraduate curricula is to help departments provide chemistry majors with a sound education in the fundamental areas of modern chemistry. The Committee on Professional Training believes that it can help departments best by setting general curricular goals rather than by specifying exact curricular structure. A department's program should emphasize strengths of the institution and its faculty. Programs ranging from ones with major emphasis on fundamental principles to ones strongly based on industrial applications have produced chemists of distinction.

Departments that seek ACS approval are encouraged to explore options for a chemistry curriculum that they deem desirable and that meet the Committee's guidelines described in the following sections.

Program Development

The Committee encourages diversity as well as quality in chemistry program development. Continued experimentation and change are needed to preserve the

vitality of chemical education and to provide suitable career options for students. Establishment of uniform programs throughout the country would not, in the Committee's opinion, promote the service of chemistry to society. Each institution should seek to define its own mission and develop its chemistry program accordingly. Experiments with the content and style of teaching are strongly endorsed. The following discussion is intended to foster such experiments and, at the same time, to provide definitive criteria for the curriculum, faculty, and facilities essential for an undergraduate professional program in chemistry.

Most undergraduate programs are organized around the traditional areas of chemistry, and these are utilized in defining curricular criteria in this document. However, many applications of chemistry require synthesis of concepts from several areas of chemistry. Also, topics normally treated in other disciplines (for example, biology and the life sciences, mathematics, physics, and engineering) are often significant components of major developments in chemistry.

Furthermore, uses of chemistry have social and economic implications. Thus, education of chemists at both introductory and advanced levels should reflect the relationship of chemistry with other disciplines and be responsive to the impact of chemical science on society. The chemistry curriculum should not be so extensive or so tightly structured as to preclude studies in mathematics, other natural sciences, or the social sciences and humanities.

An important factor in the design of a curriculum is the academic preparation and potential of entering students. Introductory courses should encourage and accommodate students with different backgrounds, potential, and career goals. Not all students may need the level and sequence of courses suitable for well-prepared, science-oriented students. It may be necessary in some areas of chemistry to offer courses with different prerequisites. Effective counseling of students and conscientious adherence to established prerequisites for registration in advanced courses are necessary if the career needs and interests of all students are to be met and course quality maintained.

Upper level and advanced courses must be given on a regular basis to permit students to schedule the courses in proper sequence and with reasonable flexibility. That regularity required for an approved curriculum may be jeopardized if enrollments are small or uncertain from year to year, so that few, if any, properly qualified students register for such courses.

The First Two Years

The introductory courses in a curriculum are critically important. Usually the majority of students enrolled in first and second year chemistry courses are not chemistry majors but take chemistry as a requirement in some other curriculum.

Chemistry departments have an important obligation to serve the educational needs of such students. That obligation is a major challenge to the profession and an excellent opportunity to make a significant contribution to the careers and intellectual development of many future citizens and community leaders.

It is important that beginning and subsequent courses in chemistry incorporate historical perspective as well as reference to current developments in chemistry. Emphasis on pure theory has too often led to neglect of the practical, aesthetic, and humanistic aspects of chemistry, not only in courses for nonscientists, but also in the education of professional chemists. Lecture experiments and demonstrations — particularly effective in presenting descriptive material and in generating lasting interest in chemical phenomena — should be employed wherever possible. Similarly, efforts should be made to use some of the current types of learning and media resources, such as computer aided instruction, slide-tape presentations, and programmed instructional materials. They may serve to challenge the individual student and stimulate both interest and learning.

Total Hours in Chemistry

No four-year curriculum can cover the whole of chemistry. The quality of education is, therefore, more important than the precise content. Undergraduate education for a successful career in chemistry does, however, require both breadth and opportunity for specialization. Many curricula may accomplish those goals.

An approved program in chemistry, exclusive of required courses in physics and mathematics, normally comprises about one-third of the total undergraduate program. In the Committee's judgment, a professional chemist should have the following experience in chemistry as an undergraduate:

- 400 hours of classroom work. Supervised reading courses, tutorials, active participation in seminars, and supervised self-study programs may be counted in the 400 hours.
- 500 hours of laboratory work. Normally, at least 400 hours of laboratory work occurs in structured courses. If more than 100 hours of laboratory research are counted toward the 500-hour minimum requirement, the Committee requests that representative student research reports be submitted. Laboratory work in undergraduate research is expected to be more narrowly focused and deeper in content than that provided in formal laboratory courses.

Normally about four-fifths of an approved program is covered in a core curriculum (see next section) spread approximately equally over the areas of analytical, inorganic, organic, and physical chemistry. The remaining portion is covered in advanced courses in chemistry or related fields.

The Core Curriculum

Programs of study in chemistry for majors and non-majors can be organized in many ways to reflect the institution's mission, the available facilities, and the interests and capabilities of the students and faculty. However organized, the core curriculum of an approved program (that part of the program taken by all certifiable graduates) must include roughly two semesters of study of each of four fundamental areas: analytical, inorganic, organic, and physical chemistry.

Initial studies should include an introduction to chemical principles, elementary quantitative analysis, and basic inorganic chemistry — the elementary quantitative analysis and the basic inorganic chemistry being equivalent to approximately a semester's work in each subject. Basic inorganic chemistry, whenever presented, should include descriptive chemistry dealing in a systematic way with the elements and the structures, properties, and reactions of their compounds. Portions of the core requirements might be completed in a course in general chemistry. For example, a general chemistry course with heavy emphasis on inorganic chemistry could satisfy as much as one-half of the one-year core requirement in that area. When parts of a general chemistry course are used to satisfy some of the core requirements, the Committee requests supporting documentation in the form of syllabi and examinations.

The remaining core material normally is covered in two semesters of organic chemistry, two of physical chemistry, one of upper level inorganic chemistry, and one of upper level instrumental analytical chemistry. Ordinarily the upper level courses in inorganic chemistry and analytical chemistry should have organic and calculus-based physical chemistry as prerequisites.

Although conventional names have been used to describe the core areas, the Committee recognizes and encourages approaches that cover the same material in different ways. All of the core courses not only must be offered but actually given on a regular schedule that enables students to take them in proper sequence.

Core courses should include examples of biochemistry, polymer chemistry, and applied chemistry, particularly if those areas of chemistry are not covered in advanced courses. Throughout the core, attention should be given to chemical safety, systematic use of the chemical literature, and computer applications.

Advanced Courses

In addition to the core, approved programs include a minimum of six semester hours of advanced work. Advanced chemistry courses are those that have a major portion of the core curriculum, usually including physical chemistry, as a prerequisite. However, a biochemistry course that uses quantitative concepts involving kinet-

ics, thermodynamics, solution properties of macromolecules, and that has organic but not physical chemistry as a prerequisite may be appropriate for chemistry majors in approved programs. Also, some advanced organic courses (for example, advanced organic synthesis) may not require a physical chemistry prerequisite. The Committee does request for evaluation copies of course syllabi and examinations for advanced courses that do not have a semester of physical chemistry as prerequisite.

Upper level independent study and research at the post-physical chemistry level may be counted as advanced work, as may advanced courses in chemical engineering, computer science, geochemistry, surface chemistry, mathematics, molecular biology, physics, and other allied fields. Because of the importance of biochemistry and polymer chemistry, those areas should receive serious consideration as topics for advanced courses. However the requirement for advanced work is met, it is essential that sufficient advanced courses be given each year in chemistry so that, if they wish to do so, students may obtain the amount of advanced course work specified in these guidelines from among courses offered by the chemistry department.

Curriculum Summary

In summary, an approved program is comprised of core material equivalent to approximately 32 semester hours equally distributed in analytical, inorganic, organic, and physical chemistry and approximately six semester hours of additional study at the advanced level. About one-half of the core material in analytical and inorganic, as well as all of the advanced courses, should follow at least a semester of physical chemistry.

Laboratory Work

Laboratory work should give students hands-on knowledge of chemistry and the self-confidence and competence to:

- plan and execute experiments through use of the literature
- anticipate, recognize, and respond properly to hazards of chemical manipulations
- keep neat, complete experimental records
- synthesize and characterize inorganic and organic compounds
- perform accurate quantitative measurements

— use and understand modern instruments, particularly NMR, IR, UV-VIS, and AA spectrometers, gas and liquid chromatographs, electrochemical instruments, and laboratory computers

— analyze data statistically and assess reliability of results

— interpret experimental results and draw reasonable conclusions

— communicate effectively through oral and written reports

To improve laboratory instruction, some schools have combined experimental techniques from such specialties as physical chemistry, chemical analysis, and synthetic organic and inorganic chemistry into integrated laboratory experiments. Care should be taken to insure that in such programs the number and types of experiments are at least equivalent to those of more traditional laboratory assignments and that integration of laboratory work, whether through structured laboratory periods or through less structured research (see below), does not result in a loss of important concepts stressed in a particular chemical specialty.

Research

Undergraduate research, as a distinctively problem-oriented rather than a discipline-oriented activity, can integrate the components of a core curriculum into a unified picture. Additionally, well-planned research should help undergraduates acquire a spirit of inquiry, initiative, independence, sound judgment, patience, persistence, alertness, and the ability to use the chemical literature. Also, supervision of research helps faculty members maintain their enthusiasm, professional competence, and scholarly productivity.

The Committee strongly endorses carefully designed programs of undergraduate research but recognizes that independent projects make heavy demands on institutional resources and faculty and student time. Proper supervision of research requires much attention by a faculty advisor, for which allowance should be made in teaching assignments. Without careful supervision, research can be dangerous, unproductive, and demoralizing.

Laboratory experience acquired through undergraduate research can be valuable whether or not the goals of the research itself are fully realized. Ideally, a research project should be well defined, stand a reasonable chance of completion in the time available to a student, avoid largely repetitive work, require that the student use advanced concepts as well as a variety of experimental techniques and instruments, and develop new chemical knowledge that might be publishable — although it is realized that that will not always be possible. *Preparation of well-written, detailed reports is an essential part of a valid program.* Generally, more than initial drafts will be required with constructive faculty criticism at each stage.

Chemical Literature and Information Retrieval

Students preparing for professional work in chemistry must learn how to retrieve specific information from the enormous and rapidly expanding chemical literature. The increasing volume and complexity of the literature means that students can no longer acquire skills in information retrieval without some formal instruction. Ability to use the literature should be imparted either through a specific course or through coordinated instruction integrated into courses primarily devoted to other topics. These could be lectures or laboratory courses, preferably at the junior or senior level. Library exercises should be included in such instruction. In institutions requiring undergraduate research, instruction in information retrieval may be part of the introduction to research, but it should be recognized that adequate presentation of the subject — including understanding of the use of *Chemical Abstracts, Beilstein, Gmelin, Science Citation Index* and other compilations, such as *Landolt-Börnstein* — will generally require formal lectures. It is highly desirable that students gain some experience with on-line interactive computer files. It is essential, however, that students understand the organization and use of printed information sources in order to use the computer readable files to best advantage.

Self-Instruction Programs

Increasingly, self-instruction programs are available to help students reach that principal goal of professional education, one vital to avoidance of obsolescence: being able to learn without the help of a teacher. The Committee recommends that departments explore (perhaps in cooperation with ACS local sections) new avenues of self-instruction materials as supplements to traditional classroom instruction. For example, audio, video, and computer courses are available on such topics as catalysis, engineering, industrial chemistry, polymers, surfaces, signal analysis, and use of the chemical literature.

Safety

Discussions of modern health and safety issues must be an integral part of the chemistry curriculum, beginning in core courses with discussions of acute and chronic toxic effects of chemicals, flammability, explosivity, and radiation hazards. Recognized safety practices should be stressed, including (but not limited to) compliance with regulations of OSHA, recommendations in the ACS manual "Safety in Academic Chemistry Laboratories" and in the NAS-NRC "Prudent Practices for Handling Hazardous Chemicals in Laboratories," and applicable state and local regulations. Students should be knowledgeable regarding the physical, chemical,

and biological properties of the substances they handle. They should recognize hazards and be prepared for worst possible situations.

Personal protective equipment (gloves, lab coats, face shields, bench shields) and appropriate facilities should be readily available for handling, storing, and disposing of hazardous materials. Regulations regarding eye protection in all laboratories should be rigorously enforced. Telephones with prominently displayed emergency numbers should be easily accessible at all times to persons working in laboratories.

Careful thought should be given to the proper supervision of students working on independent projects or at odd hours. No one should ever work in a laboratory alone.

Cooperative Education* and Industrial Chemistry

A distinctive feature of cooperative education is placement of students in industry and government. Co-op programs can provide students with:

- an appreciation of technology
- exposure to team research, interdisciplinary research, societal problems, and points of view complementary to those of academia
- a synthesis of pure and applied chemistry
- opportunities to use sophisticated instruments
- early professional experience, contacts, and information for career planning
- practice in preparing oral and written reports and in meeting deadlines

The Committee strongly endorses cooperation between the chemical industry and academic institutions in educational projects.

Field experiences may fulfill some of the objectives of advanced work, research, and self-instruction programs. Although generally not a substitute for advanced course requirements, properly supervised cooperative work for which academic credit is earned and for which a full, written report is submitted to the department may be used in lieu of research for up to 100 hours of the 500-hour laboratory requirement.

* For further information regarding co-op programs, write the Office of Cooperative Education, American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. 20036, or telephone (202) 872-4517.

Related Studies*

Mathematics, Computer Science, Physics

Students should emerge from an ACS approved program in chemistry with:

- a firm foundation in the fundamentals and applications of calculus, including knowledge of differential equations and proficiency with partial derivatives
- an understanding of the basic principles of linear algebra and practical knowledge of statistics with applications in such problems as experimental design, validation of data, and optimization procedures
- experience with computers, including programming, numerical and non-numerical algorithms, simulations, data acquisition, and use of data bases for information handling and retrieval

Work equivalent to at least a one-year laboratory courses in physics, preferably at a level involving calculus, should precede the basic course in physical chemistry and most advanced work in chemistry. Additional study of physics is recommended, particularly in areas that complement work in physical chemistry and instrumentation.

Foreign Language

Study of a foreign language, although not required, is highly recommended, particularly for students who plan to pursue graduate studies in chemistry. Although some graduate schools allow alternatives to foreign language proficiency, most Ph.D. programs in chemistry require a reading ability in at least one foreign language. In the Committee's opinion, competency in computer programming language(s) should supplement, not supplant, foreign language proficiency.

Oral and Written Communication

Employers of chemists report to the Committee that a large fraction of baccalaureate chemists write and speak poorly.

However necessary, speech and English composition courses alone rarely provide practice and motivation sufficient for the attainment of professional-level competence in technical writing and oral communication of scientific information. Frequent exercises in writing and speaking, critically evaluated by the chemistry faculty, are an essential part of a sound program in chemistry.

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* Several of the studies cited in this section are so closely related to chemistry that they may often best be taught in part, even wholly, within regular chemistry courses.

Ideally, every course should be an exercise in expressing ideas clearly. Seminars, progress reports, term papers, laboratory reports, problem sets, and examinations should be evaluated for clarity as well as accuracy. There is considerable truth to the remark that we do not understand something until we can say it clearly in words. Student tutoring and laboratory assisting are highly effective ways of consolidating a knowledge of chemistry and improving communication skills.

Other Fields

Chemistry pervades modern social and economic life. All chemists, including those whose interests focus strongly on research, benefit from an understanding of economics, marketing, and business. Courses in those subjects are recommended to the extent permitted by other academic requirements. Within chemistry courses themselves, advantage should be taken of opportunities to point out connections between science and society.

FACULTY AND SUPPORTING STAFF

At least 75% of the teaching faculty should have earned doctoral degrees in chemistry or should have equivalent experience. Their scientific and educational capabilities should be distributed over the major areas of chemistry so that upper level and advanced courses are taught by faculty qualified in each specialty. Further, their teaching effectiveness may be enhanced by contact or experience with the practical aspects of chemical technology and the broader applications of chemical science in the economy and society. This could be especially valuable to the education of young professional chemists interested in careers in industry or government. Faculty size and competence must be adequate to teach on a regular basis the full range of chemistry courses needed for undergraduate professional education in chemistry. Otherwise, students desiring such an education will be denied a suitable opportunity to obtain it. For these reasons, effective programs require a minimum of at least four full-time faculty members or the equivalent. Exceptions may occur, but they are extremely rare and usually of short duration.

Sound policies regarding salaries, teaching loads, promotion, sabbatical leaves, and tenure are essential. Otherwise, an institution will not be able to maintain high faculty morale or to attract and retain a chemistry faculty of the necessary high quality. Similarly, adequate institutional support and facilities are necessary for faculty members who are active in research themselves and/or who direct students' independent study and research. The Committee believes that women and minority students will broaden their career choices, raise their aspirations, and more fully realize their full potential when taught by faculties that include female and minority members. The Committee looks forward to annual and five-year reports that will show continuing progress in this important area of staffing.

Teaching loads are particularly important. Loads should be at a level that permits a faculty member to stay abreast of developments in chemistry and related areas, to modernize courses, and to engage in research and other types of scholarly and professional activities that promote the continued effectiveness of the individual as a teacher, scholar, and scientist. Even at smaller institutions where chemistry enrollments may not be large, teaching loads that exceed 15 contact hours per week (including laboratory supervision) for any prolonged period of time will weaken the program and erode the continued effectiveness of the faculty. Supervision of a student laboratory commits the time and energy of a faculty member as fully as the preparation for and presentation of a lecture. These factors are given considerable weight by the Committee in its evaluation of teaching loads.

Formal teaching loads are generally much lower than 15 contact hours per week at larger institutions offering strong graduate programs, where research activities are a central educational and professional responsibility of the faculty. Four-year institutions noted for quality undergraduate programs in chemistry give substantial teaching-load credit to faculty for time spent guiding independent study and student research, where the "tutorial" contact between students and a faculty member far exceeds that of conventional lecture and laboratory courses.

There should be secretarial, stockroom, and technical staff to relieve faculty members of routine chores and permit them to devote their time and effort more fully to academic responsibilities and scholarly pursuits. The use of properly supervised student assistants in the stockrooms and elementary laboratories may help to reduce faculty loads while providing worthwhile experience for the students themselves.

STUDENTS AND COUNSELING

Many career opportunities are available for baccalaureate graduates in chemistry, and students should be counseled about the different options. Minority group students and women enjoy especially attractive opportunities today, and they should be encouraged to consider chemistry as a career if they have a potential interest and the necessary capabilities. Students with strong interests and aptitudes for teaching and/or research and possessing superior academic qualifications should be encouraged to continue for doctoral study in chemistry or a related science. On the other hand, they should also be advised that the Ph.D. degree is not required for many positions in the chemical field.

Most of the career opportunities for chemists are in industry and in various independent and government laboratories. For many of these positions, knowledge of areas such as communications, business administration, economics, marketing,

and engineering is a valuable asset, and a bachelor's or master's degree may be preferable to the Ph.D. Chemistry majors should be encouraged to take courses in one or more of these fields if they wish to broaden their career options. Students preparing for professional careers in chemical science should be counseled to complete the full undergraduate curriculum described in this booklet. It provides a suitable background for many different careers in chemistry and related areas and avoids premature specialization in the subject.

Professional seminars, with or without credit, and participation in activities of professional chemical societies often serve effectively to broaden student interest in the many career opportunities available.

FACILITIES

Lecture Rooms and Office Space

Classrooms for chemistry courses and the offices for faculty should be located near the instructional and research laboratories. Classrooms should meet modern standards of lighting, ventilation, and comfort and be equipped with demonstration and projection facilities.

Student Instructional Laboratories

Laboratories should be well-lighted and ventilated and be equipped with such services as gas, water, and electric power. Hoods should be readily available and in working order. The California standard of 28 square feet and 42 square feet of working space per student for lower and upper division laboratories, respectively, may serve as a guide. Construction or renovation of laboratory facilities should be in conformance with the regulations of the U.S. Occupational Safety and Health Administration.

Faculty and Student Research Laboratories

In addition to the instructional laboratories, provision should be made for faculty and student research, again with facilities for the type of work intended, and with the capability of having semi-permanent setups for experiments that require extended periods of time.

Library

The institution should have a library within or near the chemistry building with holdings related to the size and nature of the chemistry program and the research activities of staff and students. There should be a minimum of at least 20 current periodicals, with back runs of no less than 10 years, and a range of other reference materials. The periodicals should include some journals from other countries, and, if there is a foreign language requirement, one or more journals in that language should be available.

In addition to the primary sources of information (above), there should be sufficient secondary sources, such as *Chemical Abstracts, Gmelin, Beilstein, Science Citation Index, Landolt-Börnstein*, etc., to teach students how to gain access to the chemical literature, as indicated on p. 13. The Committee realizes that subscriptions to all of these compendia are beyond the means of most colleges and some universities, but sufficient sources should be available to allow students to practice locating both bibliographic and numerical (including spectral) information. In those rare cases where *Chemical Abstracts*, with at least its volume indexes, is not available in the departmental or institutional library, the Committee requires evidence that students have ready access to it at neighboring institutions or industrial laboratories. More extensive library holdings are required at institutions where independent study and research are emphasized.

Increasingly, it is highly desirable that students have access to computer terminals through which they may interact with bibliographic and numerical data files available over computer networks.

At those institutions with a centralized main library, a departmental reading or science room is strongly recommended in order that the most important reference materials and current periodicals are close at hand when needed by staff and students, especially for those actively engaged in research and independent study.

Resource Rooms and Self-Instruction Centers

Good programs encourage self-instruction and interaction among students. Many programs include well equipped, carefully supervised resource rooms with both old and new learning aids, such as those found in the traditional reading room — elementary and advanced textbooks, handbooks, books on the history and philosophy of science and technology and on the science-technology-society interfaces, current issues of selected scientific journals, how-to-study books, and copies of old quizzes and lecture notes. Among the newer resources now provided are programmed supplements, videotapes, film strips, ACS audio courses, calculators, and computer terminal facilities.

Equipment and Instrumentation

Instruments and equipment now used in a good undergraduate chemistry program include, typically, most of the following specific items:

- analytical balances
- pH meters
- recording spectrometers (IR, UV-VIS)
- gas and liquid chromatographs
- NMR spectrometer
- mass spectrometer
- multipurpose electrochemical instrumentation
- electronic work stations

and also instruments or apparatus for the following purposes:

- radiochemistry (including counting equipment and sources)
- atomic absorption and flame emission
- calorimetry
- conductance measurements
- automatic temperature control
- computerized data acquisition

The instruments should be reasonably recent models in current use by professional chemists. In the case of complex, expensive instruments, the less costly "bench-top" models may be adequate. However, a department should have several major pieces of sophisticated equipment suitable for research as well as for undergraduate instruction. Machine shop, electronics, and glassblowing facilities should be accessible for the construction of the special apparatus often needed for research and instruction. There should also be provisions for the maintenance and prompt repair of equipment and instruments.

JOINT PROGRAMS

Undergraduate programs may be stengthened by utilization of resources of neighboring institutions, and the Committee encourages such arrangements. For example, the upper level and advanced course options may be extended and enriched in this manner. Also, the availability of library and laboratory facilities, including expensive instrumentation, may be expanded by a sharing agreement.

Another possibility is that two or more smaller institutions in the same area are not able individually to offer a professional program in chemistry. However, these institutions might combine their resources and facilities to provide a full, strong program. Under such circumstances, the Committee will consider a joint application. Each

case will be considered on its own merits but must have strong prospects of permanence, clearly stated designations of responsibility of curriculum planning and development, and established procedures for overall program administration and the certification of graduates.

There are instances in which a non-approved institution and an ACS approved institution are located in the same area and, by arrangement between the two, students at the non-approved institution enroll in the upper level and advanced chemistry course offerings at the ACS approved institution. Those students who complete the courses successfully and fulfill the other course requirements for certification to the Society may be certified by the chemistry department chair at the approved institution. Only the name of the latter institution appears on the approved list of the Society, but this plan does enable some students to receive ACS certification who otherwise might not.

CERTIFICATION OF BACCALAUREATE GRADUATES

Those chemistry majors receiving a baccalaureate degree and having completed a curriculum as described in the section on "The Curriculum" of this booklet may be certified to the Society for membership purposes by the chair or head of the chemistry department at the approved institution. Certified graduates are eligible to become Members of the Society after graduation; other chemistry graduates may become Associate Members after graduation and Members after three years of professional experience in chemistry or chemical engineering. Certification of graduates occurs only at the time of graduation with the baccalaureate degree and is the responsibility of the department chair. A student is certified provided that the department chair considers him or her to have met the requirements outlined in this booklet.

EVALUATION POLICIES AND PROCEDURES

PRELIMINARY REQUIREMENTS FOR PROGRAM EVALUATION

The ACS through its Committee on Professional Training is always glad to discuss with any member of a chemistry department and/or other officials of a college or university questions pertaining to education in chemistry at the baccalaureate, master's, and/or doctoral levels. If requested, the Committee is willing to offer suggestions and guidance to those institutions wishing to improve their educational programs in chemistry, not only for students preparing at the undergraduate level for professional careers in chemical sciences, but also for the many other students who may be seeking knowledge of chemistry to fulfill different career objectives or for general cultural and educational purposes.

A substantial number of the institutions that approach the Committee either contemplate or request the cooperation of the Society in a formal evaluation of their undergraduate professional program. In such cases, the Committee requests evidence of the following prior to the evaluation:

- accreditation by the regional association. This accreditation is important since an educational program in chemistry that meets the guidelines described previously in this booklet requires broad institutional support in areas such as mathematics, physics, the liberal arts, and, for some students, in other areas such as economics, marketing, and business administration.
- a suitable, stable organization of the chemistry program. The program organization, size and quality of the staff, curricular offerings in chemistry, and the educational facilities available for the program must have become established, and the program must have produced at least one class of baccalaureate graduates.
- completion of the evaluation questionnaire prepared by the Committee.
- an invitation by the principal administrative officer of the institution for the Society to cooperate in an evaluation of the chemistry program.

SELF-STUDY AND INFORMAL CONFERENCE

It is the practice of the Committee to hold an informal conference with the person in charge of the chemistry program as a prelude to its formal evaluation. The conference encourages frank and constructive discussion of the program and provides an opportunity for the institution to learn more about the criteria, policies, and procedures of the Committee. Administrative officials of the institution are always welcome to attend and participate in the conference. In preparation for this conference, the Committee makes available a questionnaire that helps to encourage and assist the self-study process.

The completed questionnaire and associated information provided about the program are carefully reviewed by the Committee prior to the informal conference. The results of the self-study and of the conference are used by the Committee to develop a preliminary impression of the program's characteristics, its strengths and its weaknesses, and to determine the desirability of proceeding with a formal evaluation. Following the conference the Committee decides 1) that it would be appropriate to proceed with a formal evaluation of the program (see below) or 2) that certain changes and/or improvements need to be made in the program before a formal evaluation is recommended, and information concerning these recommended changes and improvements is sent to the head of the chemistry program.

FORMAL EVALUATION PROCEDURES

If the informal review indicates that a formal evaluation would be timely, the President of the institution is requested to send a letter to the Committee indicating that a visit to the campus by one of the Committee's Visiting Associates would be welcome as the next step in the evaluation process.

The on-site visit requires one to two days during a regular instructional period. The date of the visit should be mutually convenient to the Associate and the person in charge of the chemistry program, at a time that will permit the Associate to meet and talk briefly with one or more of the principal administrative officials of the institution. The Society does not charge the institution for such an evaluation, and all costs incurred by an Associate for an on-site visit are assumed by the Society.

The purpose of the visit by the Associate is to examine for the Committee selected areas of the program where questions may exist; to obtain any additional data that the Committee needs for its evaluation; to meet and talk personally with faculty members, students, and administrative officials; and to observe the general educational and scientific environment that exists at the institution. Background material

and instructions are prepared and sent to the Associate by the Committee prior to the visit. The report of the Associate is studied by the Committee at its next regular meeting, at which time a complete review is made of all information available about the program.

The specific program areas reviewed during an evaluation are those described in the section in this booklet "Guidelines for Evaluating Undergraduate Professional Education in Chemistry." The Committee pays special attention to the overall quality of the program as judged by the number and competence of the teaching faculty; teaching loads; level, breadth, and depth of instructional offerings (especially at the advanced course level); adequacy of facilities and supporting personnel; the aptitude of its students; and the performance of its graduates. Details of program implementation (such as course titles and format) are not prescribed. The program as a whole must be up-to-date, coherent, and challenging to the students.

ACTION FOLLOWING FORMAL EVALUATION

The specific types of action by the Committee after an initial evaluation are as follows:

Approval — Program meets the criteria of the Society.

Deferral — Final decision postponed until specific additional information is provided or to allow an adequate period of time for the institution to implement planned or suggested improvements in the program.

Approval Withheld — Program does not meet the criteria of the Society, nor does it appear that program changes could be achieved within a reasonable period of time to qualify for approval.

In each case, the decision of the Committee is communicated to the principal administrative officer of the institution, and in cases of deferral and approval withheld, the area(s) in which a program was found not to be in compliance with the ACS guidelines are indicated. The principal administrative officer of an institution is free to withdraw the invitation extended to the Society for an evaluation at any time prior to the completion of the evaluation. In such an event, the evaluation is discontinued.

Although there may be minor deviations from the details of the guidelines, a program is approved if it meets the spirit and substance of the guidelines established by the Society for undergraduate professional education in chemistry. The name of the institution then appears on the list of colleges and universities whose programs have been approved by the Society. This list is published each spring in *Chemical & Engineering News* as part of the Committee's annual report.

VISITING ASSOCIATES

Visiting Associates of the Committee are experienced educators and scientists thoroughly familiar with the Society's guidelines and knowledgeable about both the administrative and technical aspects of conducting successful undergraduate programs. Meetings are held periodically with the Visiting Associates to help keep them informed about interpretation of the guidelines, evaluation procedures and techniques, and educational trends in chemical science.

In the selection of an Associate for a particular on-site evaluation visit, every effort is made to eliminate any possibility of conflict of interest or bias. For instance, a graduate of the institution under evaluation, or a person having a close and continuing relationship with the institution, would not be chosen to assist in the visit and evaluation. Neither would an Associate be selected who is a faculty member at an institution in the same immediate geographical area or from one having any substantial number of its graduates on the chemistry staff at the institution being evaluated.

ANNUAL REPORTS AND RE-EVALUATIONS

Approved institutions are expected to report annually to the Committee on changes in faculty and curricula; to provide information about the numbers and types of degrees granted in chemistry; and to certify those baccalaureate graduates who have completed a program that meets the guidelines of the Society. The statistical information concerning the numbers of graduates at the various degree levels is summarized and published each year.

Full re-evaluations of programs at approved institutions are scheduled at five-year intervals but with provision for more frequent re-evaluations in the event of significant program changes. A re-evaluation consists of completion of a questionnaire prepared by the Committee for this purpose. These reports enable the Committee also to keep abreast of trends and innovations in the teaching of chemistry throughout the country.

If the review of an institution's report as well as any other information available to the Committee about the program indicates clearly that it continues to meet the guidelines of the Society and remains healthy and vigorous, no on-site visit is required. Otherwise, an on-site visit is included as part of the re-evaluation. An on-site visit by an Associate is also arranged if requested by an institution. As in the case of initial evaluations, no charge is made by the Society for a re-evaluation or for continued listing of an institution on the approved list. The expenses incurred by an Associate for an on-site visit are paid by the Society.

ACTION FOLLOWING RE-EVALUATION

One of the following types of Committee action is taken following the completion of a re-evaluation:

Approval Continued

Probation

Approval Withdrawn

When the decision of the Committee is for continued approval, the person in charge of the program and the chief administrative officer of the institution are so advised in a letter that includes whatever suggestions and recommendations the Committee might deem appropriate to promote the continued strength and vitality of the program. If the Committee concludes that a program should be put on probation or that approval should be withdrawn, the reasons for this action are summarized in a letter to the chief administrative officer of the institution and to the person in charge of the program.

PROBATION AND WITHDRAWAL OF APPROVAL

An institution is placed on probationary status prior to any decision to withdraw approval. Probationary status occurs whenever significant changes have occurred in the chemistry department and/or program that in the judgment of the Committee might prevent the institution from offering a program that meets the Society's guidelines. Examples of such changes are crucial reductions in faculty size, in the quality and distribution of faculty capability, in course offerings, in required chemistry lecture or laboratory hours, and in budgetary support. Every effort is made first by the Committee to encourage and assist the institution to strengthen its program in deficient areas, and a period of time — usually not to exceed 12 months — is allowed the institution to correct the deficiencies and to bring the program back into compliance with the criteria.

If compliance is not achieved within the prescribed period or if the chief administrative officer of the institution indicates to the Committee that the institution prefers under the circumstances not to proceed with the re-evaluation, approval of the institution is withdrawn.

APPEALS OF ADVERSE EVALUATION DECISIONS

An adverse evaluation decision by the Committee is defined as placement on probationary status or the withdrawal or denial of approval. An institution may

petition for review of an adverse decision if it believes that the Committee has not adhered to its own established policies and procedures or has failed to consider all of the evidence and documentation presented during the evaluation. The petition should be sent to the Committee not less than 30 days followings the date of the letter advising the institution of the adverse decision. Moreover, within 60 days of submitting the petition, the institution must provide whatever additional information and documents it wishes to present in support of the petition.

Upon receipt of a petition and supporting information, the Committee will review the matter at its next regular meeting, which will include a conference with representatives of the institution if it is desired by the institution or the Committee. After the meeting the Committee will report its findings to the institution.

Every institution has the right to appeal the Committee's decision to an independent Appeals Board established for that purpose. The Appeals Board, consisting of three individuals who are not members of the Committee, is appointed annually by the Society's President and Board Chairman.

While there is no formal mechanism for appealing decisions of the Appeals Board, it is important to note that any action of any Society unit is always subject to review by the Society's Board of Directors, which has full legal responsibility for all Society activities.

PROCEDURES FOR COMPLAINTS

Any administrative official of an institution, department chair, faculty member, student, or other person who disagrees with one or more of the policies, procedures, or activities of the Committee and wishes to present a complaint should do so in a letter to the Committee with appropriate documentation. The same procedure is to be followed should the complaint allege failure of an approved institution to adhere to the ACS guidelines or allege that there is a situation tending to jeopardize the quality and vitality of a program at an approved institution. It will then be the responsibility of the Committee to investigate the matter and to advise the complainant of the Committee's conclusions following the next regular meeting of the Committee.

CONFIDENTIALITY OF INFORMATION

Institutions requesting the cooperation of the Society for the evaluation of their undergraduate programs of education in chemistry are expected to provide the Committee with detailed information pertinent to the programs. Institutions on the

approved list of the Society are obligated to do so periodically as one of the conditions for continued approval. The information provided and all related discussions and correspondence between the Committee and an institution are solely for the confidential use of the Committee. However, in the event that an institution appeals a Committee decision, the Committee would release to the appeal bodies the information necessary for the proper conduct of the appeal.

In its annual published reports the Committee identifies those institutions whose programs are currently approved as meeting the ACS guidelines for undergraduate professional education in chemistry. These annual reports also summarize statistical information provided by each institution about its chemistry graduates. Otherwise, the Committee does not release information about a particular program or evaluation.

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